The Apollo γ-ray array for HELIOS

Experiment development :

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Nuclear reaction and mass models:

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Supernova modeling :

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ATLAS Users Meeting on May 15-16 2014

Addition of gamma detection for transfer reactions expands physics output

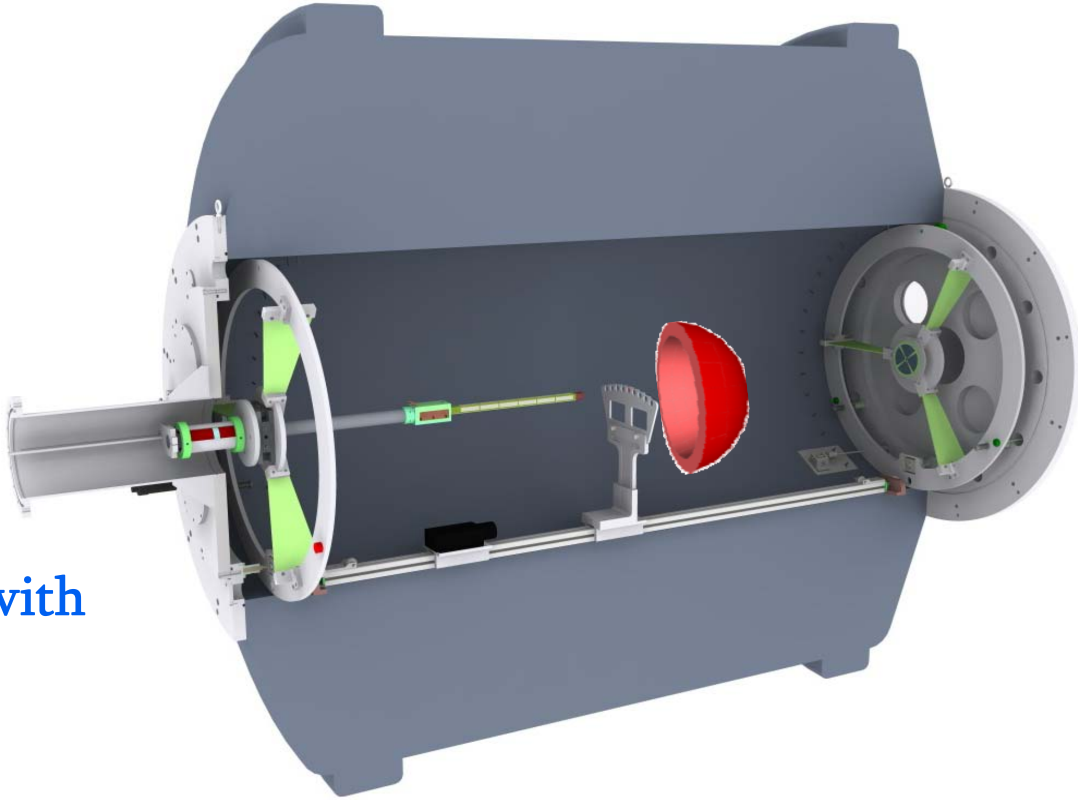
Prediction of neutron capture rates can be improved by studying

Level densities

γ-ray decay schemes

γ-ray multiplicities

Photon strength function

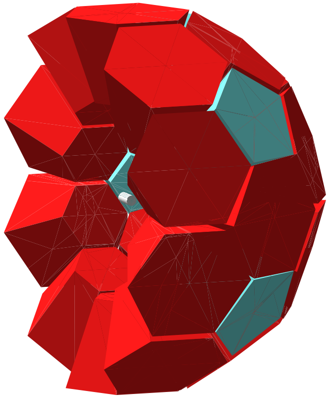


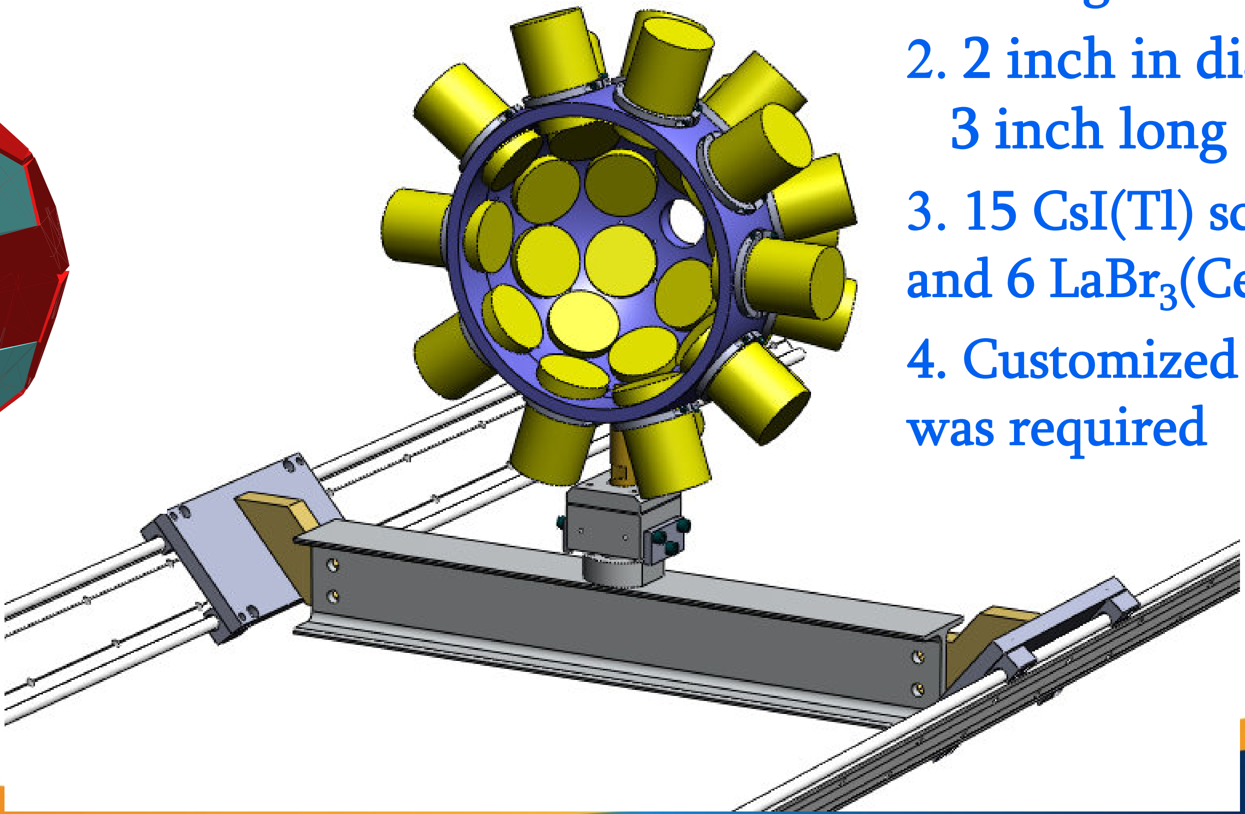
Design goals :

1. highest detection efficiency with segmentation
2. Operate inside HELIOS – 3 T magnetic field and vacuum
3. portable

Segmented γ-ray detector array

Ideal :
tapered 20 hexagons and 6 pentagons as a closely-packed geometry





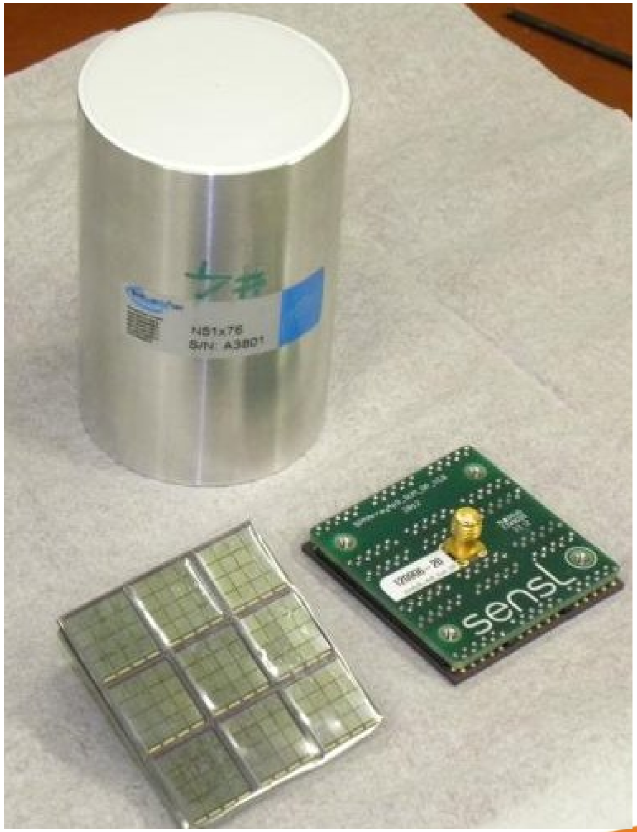
Realistic solid angle coverage :

1. 26-cylinder geometry covering about one π
2. 2 inch in diameter and 3 inch long
3. 15 CsI(Tl) scintillators and 6 $LaBr_3$(Ce) scintillators
4. Customized light readout was required

Light readout under magnetic field

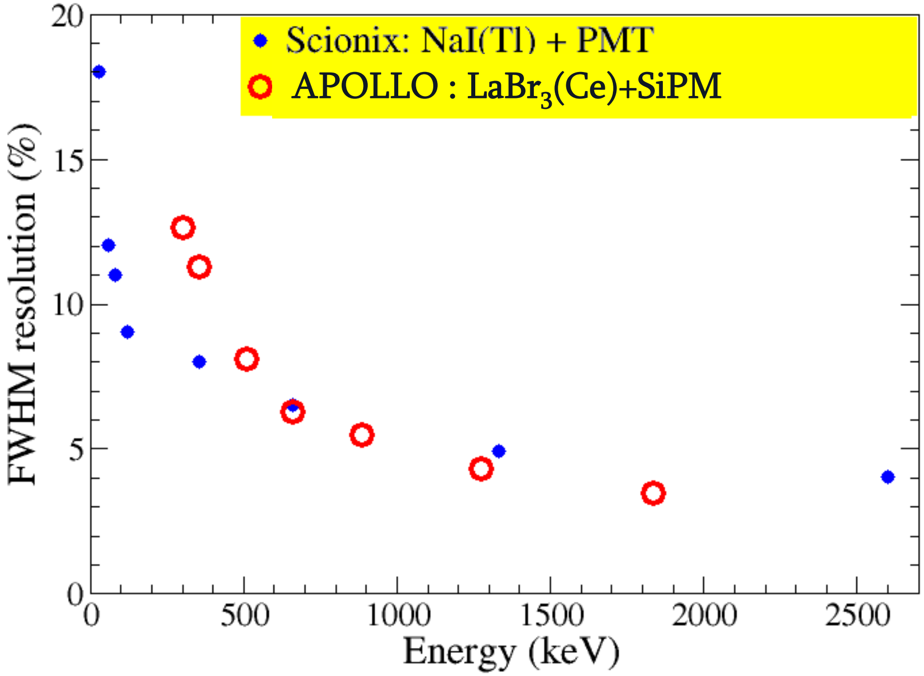
Sensl-silicon photomultiplier (SPM)

1. 36 X 36 mm^2 pixelated avalanche photodiodes
2. Used the wavelength shift paint for BrilLanCe380 (λ =380 nm), since quantum efficiency (QE) peaks at λ= 550 nm, optimized for CsI(Tl)
3. SPM + power supply + preamplifier was provided by Sensl

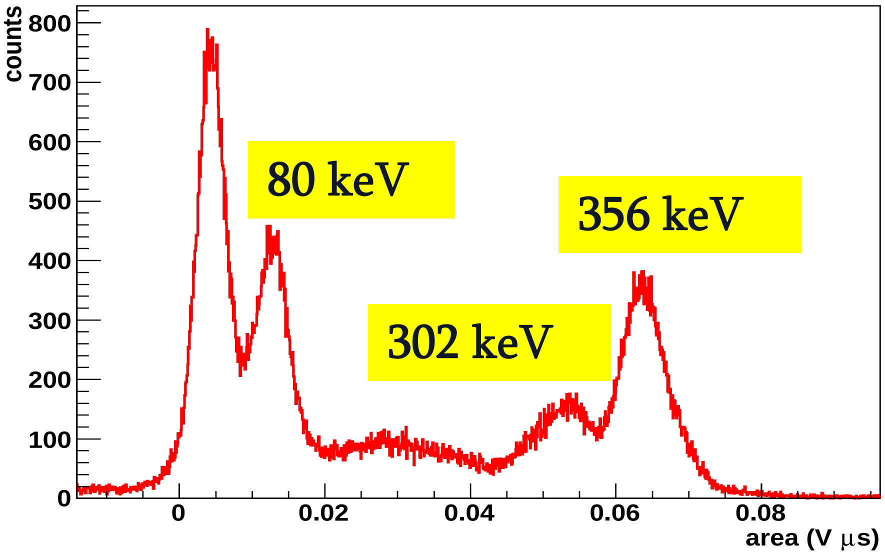


Apollo array
: measured energy resolution and efficiency

Above 1 MeV, the resolution is less than 4 %

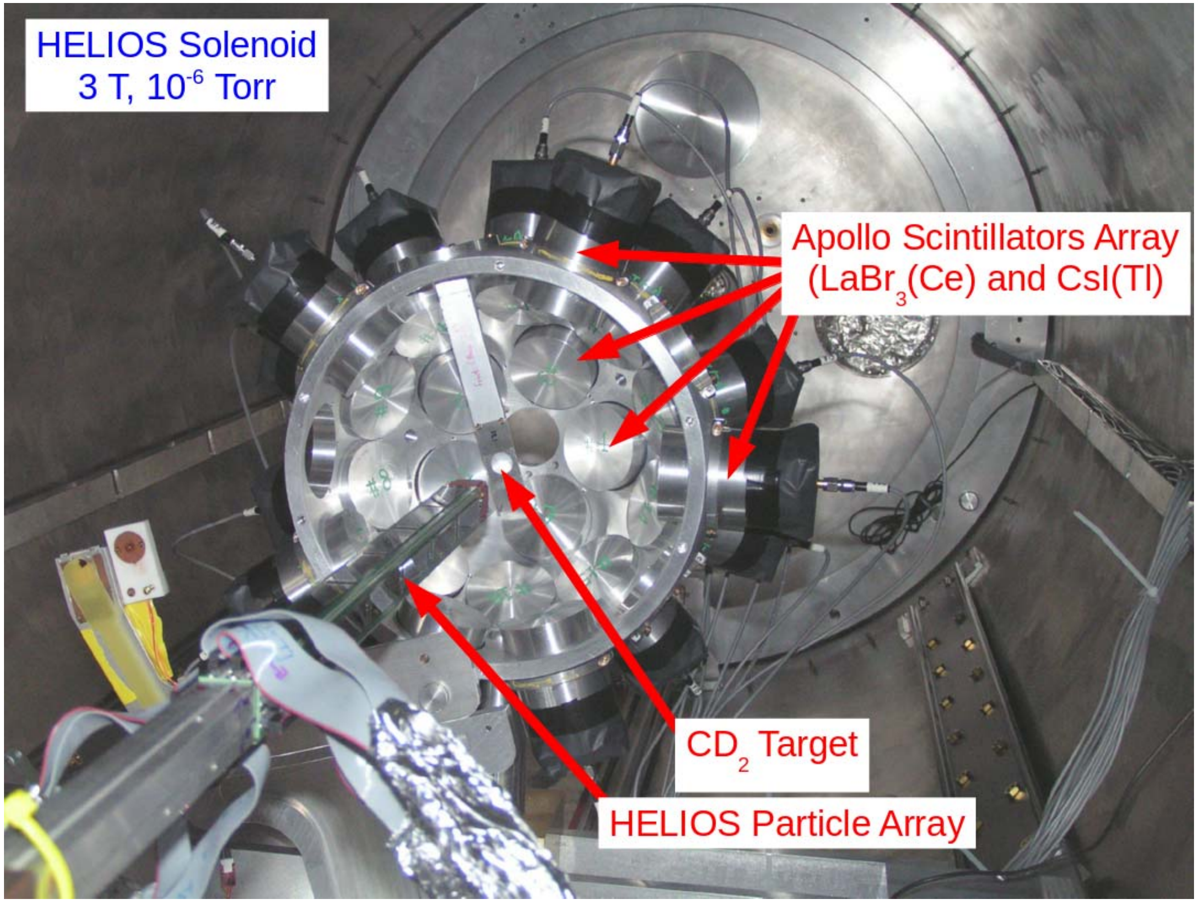


Measured γ-ray energy spectrum of ^{133}Ba source shows a good separation of 50 keV at 300 keV



Apollo peak efficiency is measured to be about 15 % at 1 MeV

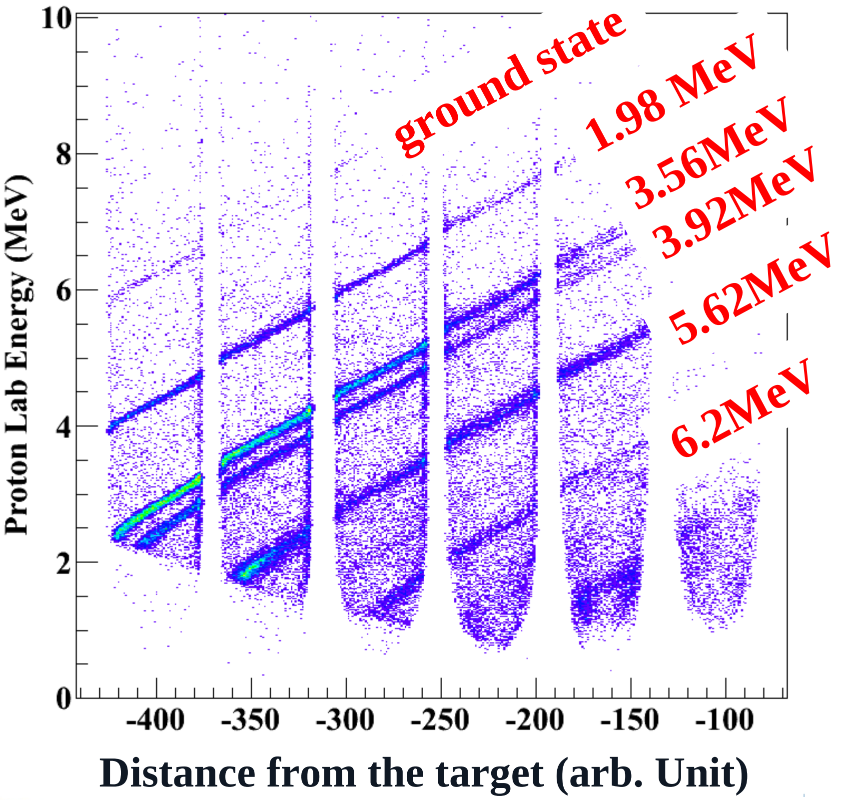
Apollo is implemented inside HELIOS



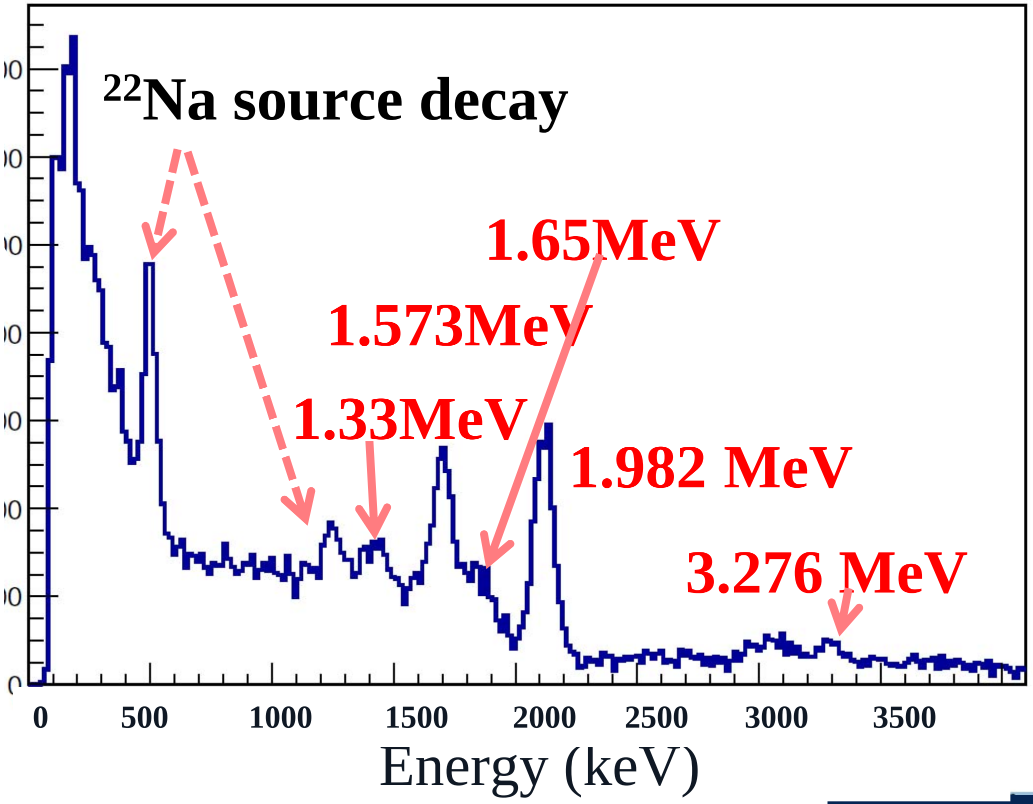
Successful commissioning experiment of the APOLLO array in Jan. 2013 for performing in vacuum and under the magnetic field with γ-ray sources

First beam test at ANL : $d(^{17}\mathrm{O},p\gamma)^{18}\mathrm{O}$

Proton groups detected by Position Sensitive Silicon array in HELIOS



γ-ray decay transitions observed by APOLLO in coincidence with the excited states of ^{18}O.



Further improvements can be done

Energy resolution

1. Sensl has developed the shorter wavelenth SPM (λ_{peak} = 420 nm)
2. Shorter shaping time or baseline restoration using digital filters.
3. Replace CsI(Tl) with $LaBr_3$(Ce)

Efficiency

Closely packed geometry

Flexibility

1. Implementation with digital electronics
2. Coupled with other instruments

Path Forward

- We have developed the APOLLO array to measure γ-rays in coincidence with transfer reactions for exploring the nuclear properties off the stability.

- Currently the stable ^{136}Xe beam time has been scheduled in June 2014 in order to test the system with heavy beams. Upon the success of this, planning to expand to unstable isotopes.

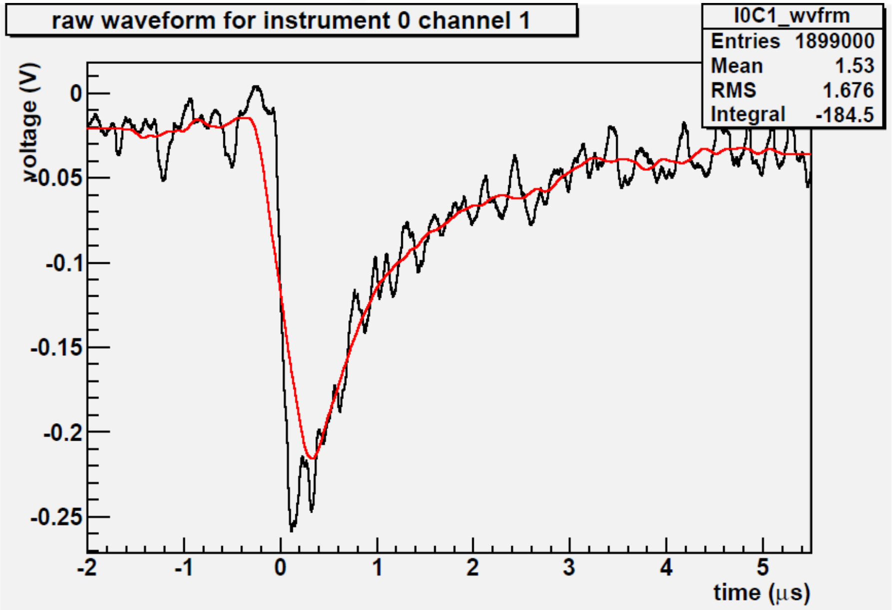
Extras

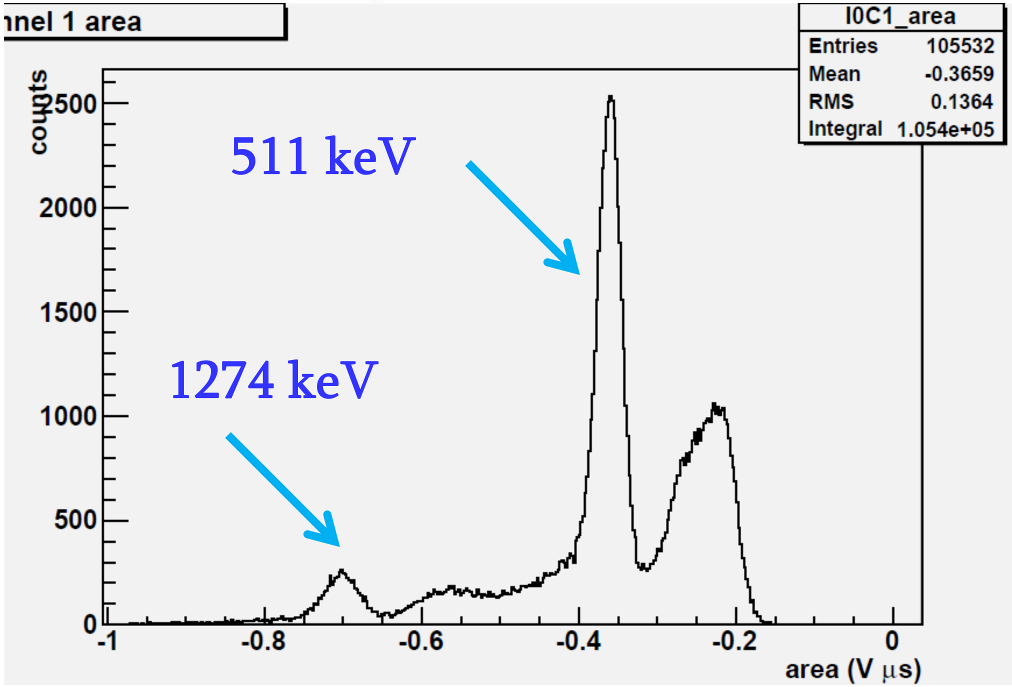
Details

- Timing -- Sensl is sensitive to this issue
  - Best results have been achieved using digital filters
- Total cost :

- $150 k for Sensl for 30 modules, including R&D
- Now $ 2k for only SPM
- LaBr3(Ce)- $13k for 2X2 LaBr3 $17K for 2X3

Digital signal processing : digital filter





511 keV

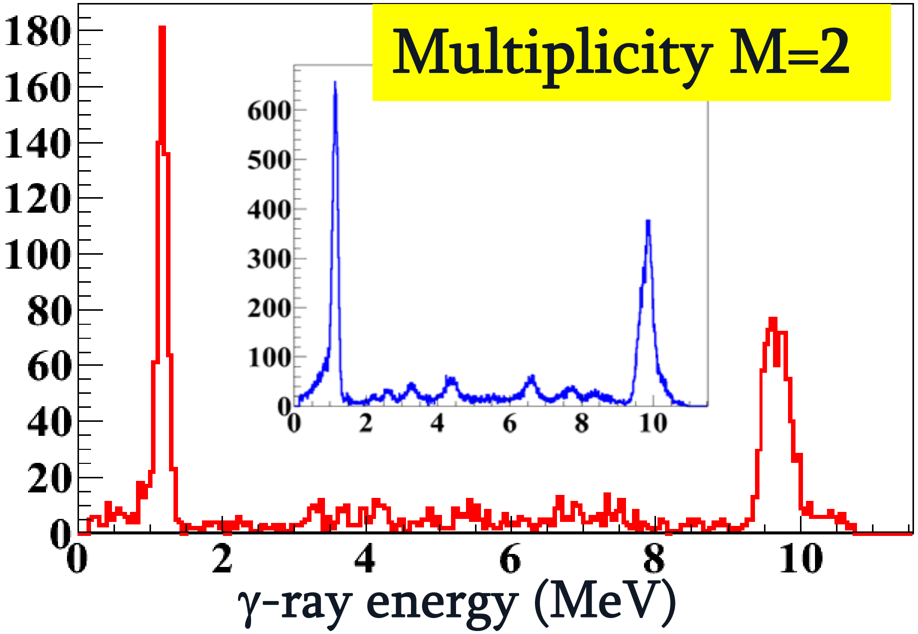
1274 keV

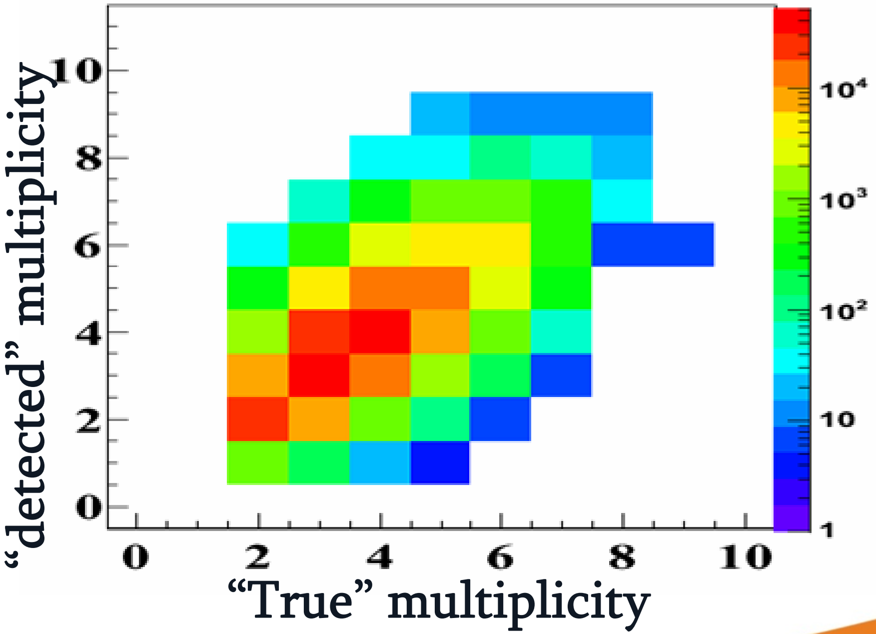
- ^{22}Na calibration source was used.
- After the peaks are detected, the waveform is integrated over 5 µs.

How to tie this γ-ray data with Monte-Carlo Hauser-Feshbach calculation?

We have demonstrated how to deduce nuclear properties using Monte-Carlo Hauser-Feshbach code (MCHF) with DANCE data at LANSCE

^{43}Ca(n,γ) measurement at LANSCE : E_R= 5.18keV (3^-)





RED : DANCE data, BLUE : MCHF + GEANT4 simulation

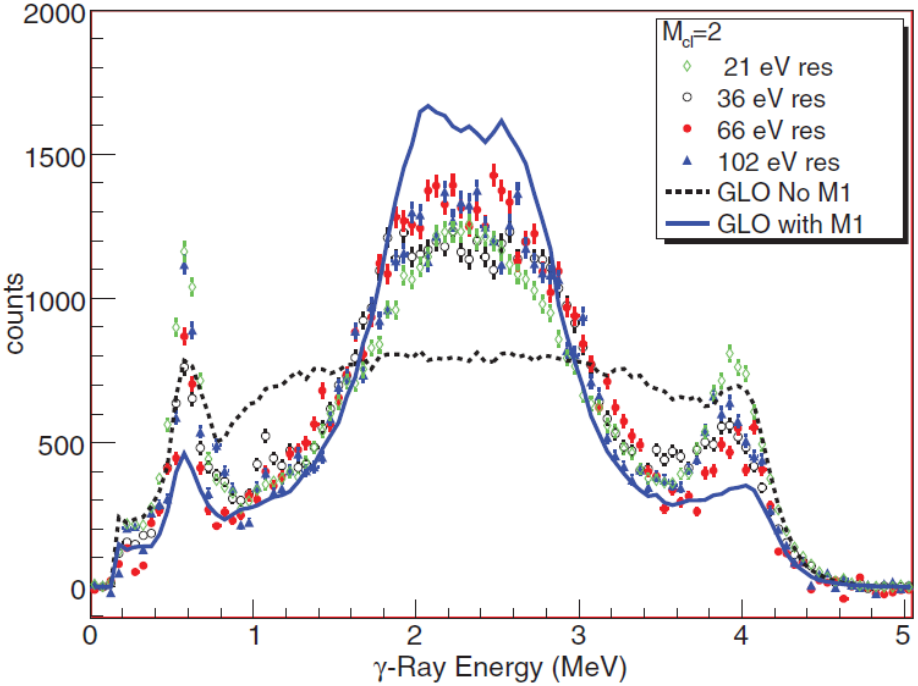
How to tie this γ-ray data with Monte-Carlo Hauser-Feshbach calculation?

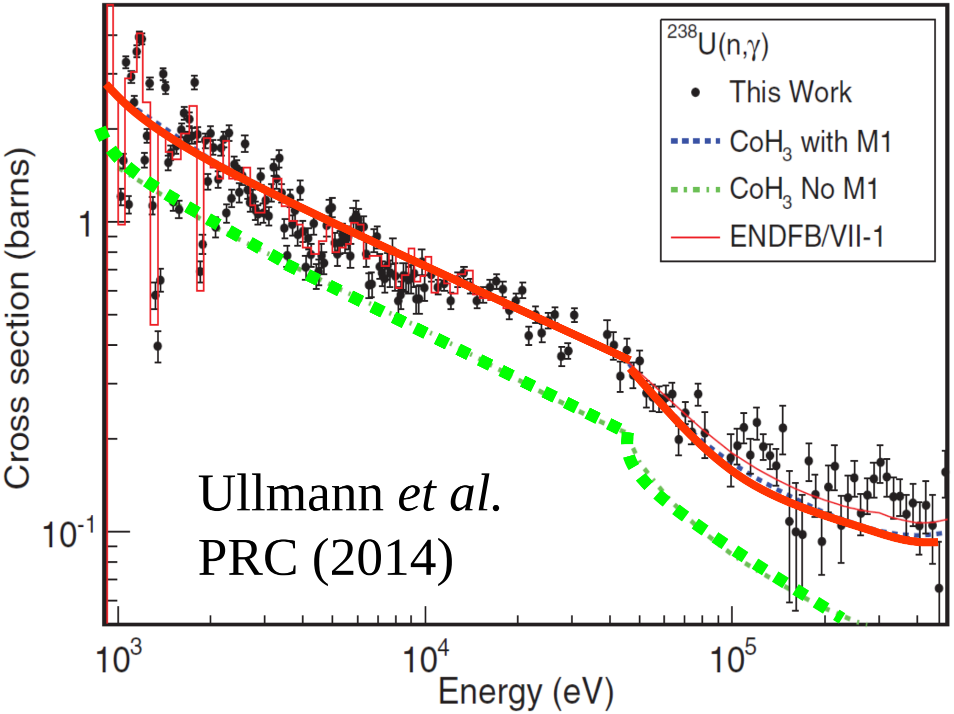
Nuclear properties are deduced using Monte-Carlo Hauser-Feshbach code (MCHF) with DANCE ^{238}U(n,γ) data at LANSCE

2-step γ-ray cascade shows better fit with M1 strength

Better nuclear input feeds →

Calculated MCHF cross section is improved





Ullmann *et al.* PRC (2014)